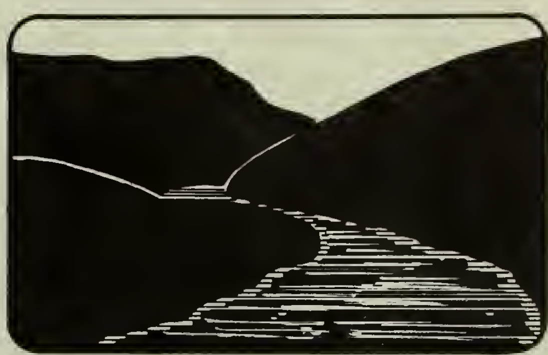
1985 Workshop and Management Recommendations



Acidic Atmospheric Deposition

Delaware Water Gap NRA

National Park Service

ACIDIC ATMOSPHERIC DEPOSITION IN
DELAWARE WATER GAP NATIONAL RECREATION AREA:

Proceedings of a Workshop, January 18, 1985
and
Management Recommendations

Milford, PA

February 1985

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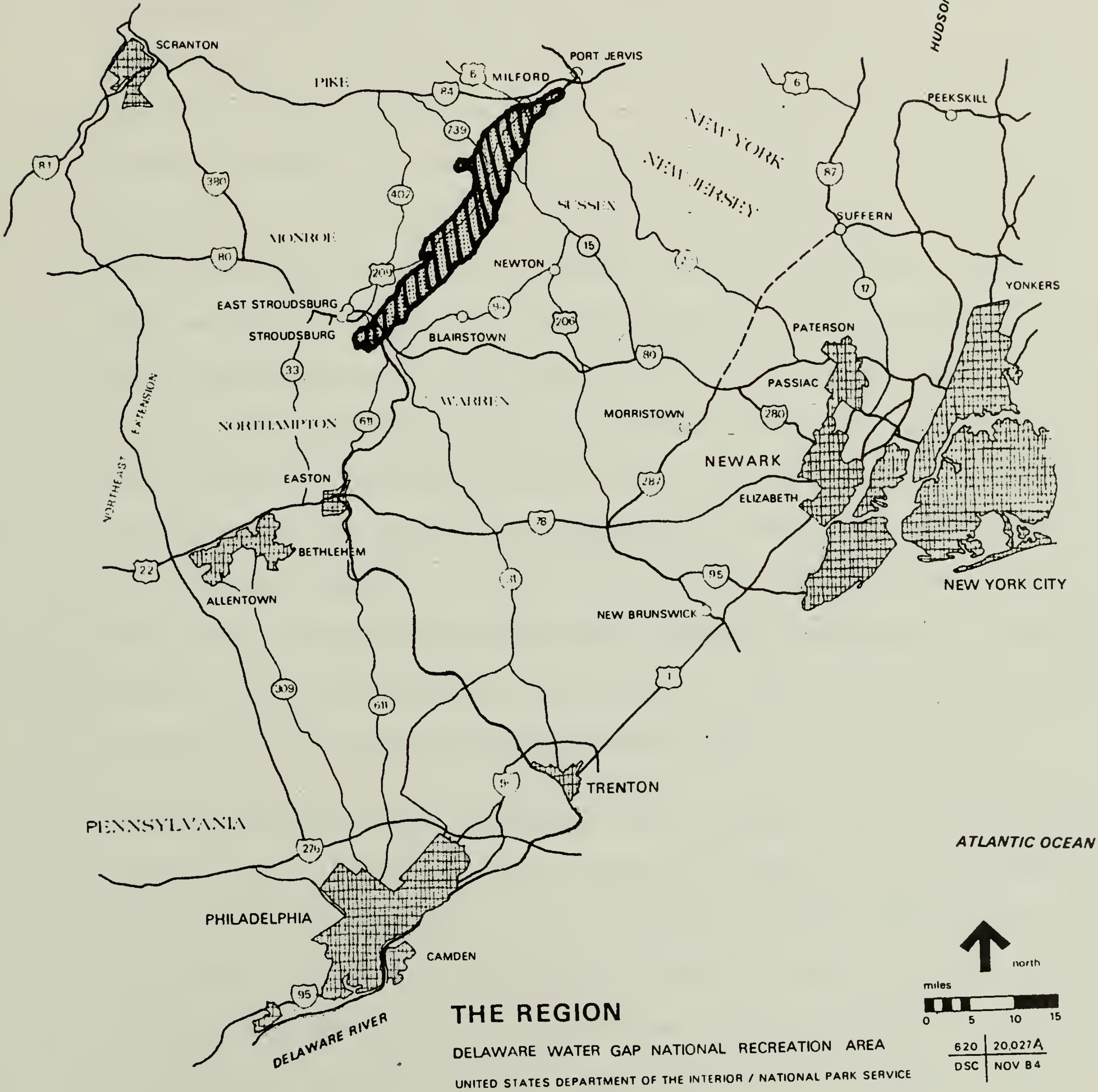

THE REGION

DELAWARE WATER GAP NATIONAL RECREATION AREA

UNITED STATES DEPARTMENT OF THE INTERIOR / NATIONAL PARK SERVICE

INTRODUCTION

Acid rain, or more generally, polluted atmospheric deposition, is falling on the northeastern United States. Deposition near urban centers has probably been polluted with metals and oxides of sulfur and nitrogen since the rise of industrialism. Lying as it does in the corner of New York, New Jersey and Pennsylvania surrounded by smelters, mills, power plants and large cities, Delaware Water Gap National Recreation Area has been the recipient of acidic deposition for a long time. With the building of tall stacks in the nineteen fifties the region has endured the added insult of long range transport of acidic materials from other industrialized regions of the country. Annual volume weighted deposition pH has been recorded as averaging around 4.3 in this part of the United States since 1979 (NADP 1985), well below the natural pH range of 4.8 to 6.0 (Charlson and Rodhe 1982). Strong acid anion (sulfate and nitrate) loadings are between 30 and 40 kg/ha/yr (NADP 1985). These values are well beyond the threshold values (pH 4.7, which corresponds to strong acid anion loadings between 20 and 30 kg/ha/yr) developed empirically by Henriksen (1980) for when environmental degradation occurs in sensitive aquatic ecosystems due to polluted atmospheric deposition.

There are sensitive aquatic ecosystems within Delaware Water Gap NRA, some of which are already acidified. These include water bodies such as Long Pine Lake and Catfish Pond on top of the Kittatinny Ridge, a slow-weathering outcrop of metamorphosed schist with thin overlying soils. Other aquatic resources at risk include Vancampens Brook, a trout stream suspected of currently undergoing acidification, and many ephemeral ponds which serve as breeding grounds for salamanders.

Because of concern for these aquatic resources a workshop was sponsored by Delaware Water Gap NRA on January 18, 1985. The purpose of the workshop was to bring together scientists conducting research in or near the Recreation Area in order to foster communication and help the Area staff develop management options for atmospheric deposition monitoring, research and mitigation. The workshop was a resounding success, as the abstracts which follow will show. High quality research is being conducted throughout Pennsylvania and New Jersey on a full suite of topics, including deposition composition, water chemistry, sediment-water and soil-water dynamics, and biological effects.

The abstracts of presentations made during the workshop start with a discussion of deposition chemistry by James Lynch, coordinator of the Pennsylvania State deposition monitoring network. Three papers on acidification effects work within the Recreation Area are presented by Bruce Pyle and Bill Stansley of the NJ Bureau of Freshwater Fisheries, Alan McIntosh and Mark Sprenger of Rutgers University, and Samuel Faust and Renae Schmidt, also of Rutgers. The latter two pertain to biogeochemical processes. Papers are presented by Deborah Lord, U.S. Geological Survey, and Mark Morgan, Rutgers University, on research on the effects of acidic deposition in the New Jersey Pinelands. This work focusses primarily on hydrogeochemical and biochemical processes. Much needed survey work on the spatial and temporal extent of acidification in Pennsylvania is reported in the next four abstracts by John Sherman from the Academy of Natural Sciences, Dean Arnold of the US Fish and Wildlife Service, Patricia Bradt of Lehigh University, and Fred Johnson of the Pennsylvania Fish Commission. The effects of acidification on organisms is discussed in many of the abstracts above, and is the specific topic of the last abstract presented by Joseph Freda from Penn State. His work on the susceptibility of amphibians in temporary

forest ponds may be especially applicable to the Recreation Area. The presentations by Arnold and Faust discuss mitigation techniques, a topic which may also be of great interest to Delaware Water Gap NRA.

National Park Service Areas have five options open to them for addressing the threats of acidic deposition. The options include: 1) doing nothing, 2) identifying and surveying sensitive resources, 3) monitoring for change in both deposition chemistry and resource response, 4) initiating or soliciting research, and 5) manipulating resources to reverse the effects of polluted atmospheric deposition. Because of the complexity of natural ecosystems it is imperative that land managers understand as much as possible about ecosystem processes. Only through knowledge can we hope to foresee the ramifications of different management applications. Delaware Water Gap NRA is well along in both surveying sensitive ecosystems and monitoring the effects of atmospheric deposition on resources, thanks in large part to contributing scientists. Questions that a workshop like this one can answer include: what is the current status of information; what needs to be known; what unique resources exist at the Area; and what opportunities are there for researchers and Area managers to work together to answer these questions? It is hoped this workshop was the beginning of a communication link that will provide the basis of sound resource management in the future.

A very limited amount of National Park Service acid deposition program dollars have been available for research in Delaware Water Gap NRA in the past, and unfortunately, that scenario will likely continue. Contributed or independent activities such as are reported in this Proceedings are therefore extremely important to Recreation Area research programs and information bases.

Investigators developing proposals for either NPS or non-NPS funding sources are encouraged to contact the Superintendent concerning the possibilities and advantages of conducting research at Delaware Water Gap NRA. The National Park Service can often provide scientific, logistical, and sometimes even financial support to a project which will help make the Recreation Area more capable of managing its resources. National Park Service lands can often provide study sites with known histories of management practices, natural disturbances and conditions.

It must be noted that the approval of the Superintendent is required to conduct any research project within Recreation Area boundaries. Proposals for research, including those with independent funds, that utilize any part of the park must be submitted for review by park staff to insure compatibility of research methods and procedures with NPS management policies and Delaware Water Gap NRA management objectives. This type of review also insures that study sites are not disturbed by park management actions or other research activities. And, the communication process begun by this workshop will be continued and expanded. Recreation Area natural resource managers will have the opportunity to make the most informed management decisions regarding the effects of atmospheric deposition on Area resources.

If planned research interests and activities coincide with the research problems and priorities discussed in this volume, investigators are encouraged to contact the Superintendent regarding the possibility of working within the Recreation Area. National Park Service personnel welcome the opportunity to discuss and explain on-going and needed research programs and how they may be operated to enhance the National Park Service management process. Inquiries

should be addressed to the Superintendent, Delaware Water Gap National Recreation Area, Bushkill, PA 18324.

SUMMARY OF WORKSHOP

Resource managers that are concerned about the effects of acidic atmospheric deposition on park resources must obtain information from a number of scientific and management disciplines. The wealth of information gathered in the following papers of this volume illustrates that even an area with limited means can obtain needed information. Delaware Water Gap National Recreation Area staff greatly increased their understanding of the atmospheric deposition issue simply by bringing regional experts together. What follows is a list, by no means exhaustive, of the kinds of information a park manager should have to maintain a working knowledge of the status of acidic deposition and effects research. Many of the investigators have published reports on the results of their work, and they are referenced so the reader may follow up on an abstract to obtain more detail. Other articles which display the current state of knowledge on this issue are also referenced.

DEPOSITION

Managers need to know the quality of wet (and dry, when information becomes available) deposition so they can determine if there is a problem. Monitoring on a regular basis allows the manager the capability of recording seasonal or even longer term changes in composition. Calculation of volume-weighted amounts of sulfate and nitrate in deposition can provide an estimate of the pollutant load placed upon natural or man-made environments. Managers must also understand the meaning of a certain pH value or a deposition rate of so

many kg/ha. The combination of information and understanding is needed for both strategic planning of management activities, and for providing answers to many questions raised by park visitors about "acid rain" in National Park Service areas.

Deposition chemistry is regional in nature (Gorham et al. 1984), so that each National Park Service unit need not necessarily mount a separate monitoring program of its own. For Delaware Water Gap NRA, two networks have already established sites nearby. One network, operated by the State of Pennsylvania was reported on at this confererence by Jim Lynch. The other is the National Atmospheric Deposition Program (NADP) network. Both operate a site at the Gifford Pinchot Institute for Conservation Studies in Milford PA in conjunction with the Northeast Forest Experiment Station of the U.S. Forest Service. Both networks concur that deposition is indeed acidic, being composed of weak sulfuric and nitric acid solutions. The northeastern part of Pennsylvania is the area which receives the least amount of acidic deposition (Lynch, et al. 1985). Annual reports are available from the Pennsylvania network, and quarterly and annual reports are available from NADP (NADP 1985). Managers from both networks are available to interpret findings.

SENSITIVE RESOURCES

Acidic deposition by itself is not enough to cause an acidic deposition problem. Parks must also have sensitive receptors. These are resources which will be detrimentally altered in the advent of increased acidity. If the onset of acidic deposition occurred some time ago, sensitive resources may have already negatively responded. A discussion of sensitive receptors can be

divided into two parts: one which identifies the resources at risk, and the other which delves into the processes involved in acidification.

Resources at risk

The most widely recognized targets of acidification are surface waters such as lakes, streams, ponds and their accompanying biota (Henriksen 1980). Surveys of surface waters measure pH values, the amount of buffering capacity available to counter incoming acidity, concentrations of basic cations, such as calcium and magnesium, and the concentrations of the strong acid anions, sulfate and nitrate, which are responsible for acidification (Galloway et al. 1984). The presence or absence of metals that are toxic to aquatic life is highly dependent upon pH, so at low pH levels analyses are sometimes made of the concentrations of aluminum, zinc, cadmium, lead, and mercury (Stumm and Morgan 1981). The results of a survey can be used to interpret the status of particular lakes and streams, such as those found within Delaware Water Gap NRA, or can be used to generate statistics about entire geographical regions. Both types of results were reported on in this workshop. Surveys of specific lakes, within and near the Recreation Area, were reported on by Patricia Bradt (Bradt et al. 1984) and Alan McIntosh. Surveys of a broader geographical area were discussed by Dean Arnold (Arnold et al. 1985), Fred Johnson, and John Sherman. Both types of surveys are important to a National Park Service area; the first because it increases knowledge of threats to natural and cultural resources, and the second because it places those resources in a larger context. The local and regional context for DEWA, unfortunately, is one of sensitive or acidified waters.

The change in aquatic biota that accompanies acidification is profound (Singer

1981, Haines 1981). Trout, which are sensitive to low levels of pH and high levels of aluminum, respond with lower reproductive and growth rates, spawning failure, and physical deformities. Ultimately, trout populations disappear from acidified waters. The report by Bill Stansley suggest this appears to be happening in Vancampens Brook. In lakes within the Recreation Area such as Long Pine Pond and Crater Lake, trout populations have failed, and only yellow perch is currently surviving due to its greater tolerance to low pH environments. Alan McIntosh reported on the fish of these lakes, as well as metal concentrations found in aquatic macrophytes, benthic macroinvertebrates, water and sediment. Algae, which were not reported on at the workshop, are excellent indicators of chemical change in lakes since many species have narrow pH ranges in which they can survive. As water becomes more acidic, algal composition shifts toward more acidophilic communities (Charles 1985). Frequent sampling of waters may capture this shift, and examination of sediments may provide a historical view of acidification trends (Davis and Andersen 1985). Temporary forest ponds also harbor organisms sensitive to acidification. The salamanders that breed in these ponds are an important component of the terrestrial food chain, and the mechanisms involved in their demise are under study by Joseph Freda. Freda has completed a survey of the temporary ponds of Delaware Water Gap NRA (Freda 1985). His findings suggest the amphibians that utilize these waters are not yet in danger due to adequate terrestrial buffering mechanisms maintaining the pH and calcium levels of these ponds. Other organisms that may be vulnerable to acidification include ducks and other animals that forage from open waters (Lund 1975). To date there has been very little research conducted on the vulnerability of foragers, and nothing was reported at the workshop.

The dieback of coniferous forests is becoming more and more widespread throughout northern Europe (Ulrich and Pankrath 1983), and recently the symptoms of dieback have been noticed in coniferous forests of the eastern United States (National Research Council 1981). The mechanisms responsible for forest decline are obscure, but some synergism between acidic atmospheric deposition and photochemical oxidants is a possible cause. Other mechanisms that have been proposed include a luxury uptake of nitrate from deposition, which causes trees to continue growing at times of the year when they should be hardening off for winter. The advent of cold weather then causes extensive frost damage to shoots and needles that would otherwise be better prepared. Photochemical oxidants, such as ozone, have been shown to lower photosynthetic rates in vascular plants (Reich and Amundson 1985). The implication from this evidence is that growth rates of vegetation throughout the eastern US may be slower than in pre-industrialized times. Still other hypotheses for forest decline include increased uptake of toxic metals, such as aluminum, from soils into plant tissues, a deterioration of protective waxy coatings of needles due to exposure to atmospheric acids, and increased susceptibility to disease caused by greater environmental stress placed on individual trees. Surveys of the status of coniferous forest resources in Delaware Water Gap NRA can be conducted by properly trained personnel, but it is scientifically too early to suggest causal mechanisms for forest damage. No forest effects work was presented at the workshop.

There is a theoretical effect of acidic atmospheric deposition on soils, but any resulting changes have not been well documented. Soils are complex and are buffered by many separate mechanisms (Krug and Frink 1985), so that chemical

change may occur only after a very long exposure to acidic material. Buffering within soils comes from continual weathering of parent materials which release basic cations and alumino-silicates into the soil environment (Norton 1979). The chemistry of aluminum is such that it provides a buffer to pH change (Reuss 1983). Clay minerals formed from weathering of parent materials, and organic matter within the soil provide buffering from adsorption and exchange reactions (Galloway et al 1983, Swank et al 1984). Biological activity within the soil yields a constant source of carbon dioxide, another buffer to acidification (Norton and Henriksen 1983). Theoretically, all these buffering activities within a soil could be exhausted, allowing for loss of soil fertility, but it will be very hard to document. Sam Faust and Renee Schmidt address buffering processes in work they are conducting in lake sediments. They suggest the extensive buffering capability of clay minerals might be used to mitigate lake acidification by artificial additions of these minerals to waters. Mitigation will be discussed in another section. The effects of atmospheric deposition that flows through soils before reaching surface waters is also another topic that will be discussed below.

Discussion of resources at risk would be incomplete without mention of the susceptibility of man-made materials. Erosion of limestone and marble monuments, painted surfaces, and metal statuary is accelerated when there is increased acidic deposition. Inventories of suspected sensitive artifacts can be made using photo-documentation of detailing that is likely to weather in coming years. None of this was reported at the workshop, and a national program sponsored by the National Acid Precipitation Assessment Program (NAPAP) is underway (Herrmann and Flinn 1985).

Processes

Inventories and surveys of resources at risk go very far in determining the extent of an acidification problem in a park area. If a manager wants to know how acidification occurs, and what are mediating factors, the processes involved with acidification must be examined. Lakes and streams for example, may receive acidic deposition directly onto their surfaces, but a far greater amount of that acid load will be altered as it flows through soils and interracts with the materials of the watershed above them (Cosby et al 1985). Mark Morgan and Deborah Lord both reported on process work they are conducting in the Pine Barrens of New Jersey. Morgan's work examines the importance of microbial iron and sulfur metabolism in influencing the chemistry of water that eventually reaches streams (Morgan 1984). Lord is investigating the role of organic matter in binding or mobilizing metals such as lead and aluminum, as well as developing models that will represent soil-caused alterations of deposition. Work proposed by Bill Stansley will examine the chemistry of intergravel water in Vancampens Brook, to determine if there are complicating factors involved in the spawning of trout. This intergravel water, where young trout develop, may have lower pH values due to increased respiration of the trout as well as other organisms. Another type of process work was reported on by Alan McIntosh. He and his students are examining the mechanisms responsible for metal uptake in organisms of aquatic lakes. Process work was not reported for forest effects, or man-made materials degradation, but such research is underway in the eastern United States, and managers should be on the lookout for reports of findings.

MITIGATION TECHNIQUES

It is without doubt that the causes of acidic depisition are industrial and automotive, and that the ultimate cure will be to reduce emissions from those sources of the components, sulfates and nitrates, that are responsible for adverse effects. Such a cure, however, may be a long time coming. In the meantime, a number of mitigation techniques are being developed which can be applied to a specific resource to prevent a specific adverse impact. Several of these were discussed at the workshop. Dean Arnold and Patricia Bradt are both experimenting with the application of lime to lakes and streams as a means of maintaining pH and fish habitat in Pennsylvania. Sam Faust and Renee Schmidt hypothesize that lining lake bottoms with base-rich clay minerals might provide needed materials for buffering incoming acids. Both of these techniques might accomplish the same goal, that of a short-term reduction in the acidification process. Repeated applications of lime or clay minerals would be necessary to maintain the desired chemistry because of the constant input of acidic materials from the atmosphere. The benefits of preventing acidification of a body of water must be weighed against the significant costs in materials, time and manpower involved (Wright 1982). The environmental implications of adding these kinds of foreign materials to bodies of water is under study by the NAPAP and needs to be carefully examined by any park considering such a technique.

STAYING CURRENT - MAINTAINING LEVELS OF INFORMATION

This workshop was an excellent means of informing Delaware Water Gap NRA managers of current regional acidic deposition and effects research. The Recreation Area might consider repeating these gatherings on a five year basis, or incorporating research reporting into regional science conferences.

Continued contact with local investigators is probably the best avenue open to an area like Delaware Water Gap NRA for addressing acidic deposition effects questions. The unique resources in the Recreation Area make it attractive to researchers, and as long as there is a give- and-take of information and cooperation, a continuing relationship can be established.

There are other ways of staying current with the science of acidic deposition effects. Publications such as the "Acid Precipitation Digest" or the NAPAP Annual Report to Congress (1984) are available. The first is a monthly digest of publications, news and meeting announcements related to the field of acid deposition. The second is an annually updated report of the research funded by this umbrella of federal agencies (including the National Park Service). Other reports are available, and are usually announced in the "Acid Precipitation Digest".

Another way of obtaining information is to maintain contact with the National Park Service Atmospheric Deposition Coordinating Committee. One of the primary objectives for forming this committee is to develop an information flow to park areas and regions of NAPAP and other research activities. Chairman of this committee is William P. Gregg of the National Park Service Washington Office.

ABSTRACTS OF

PRESENTATIONS GIVEN

AT THE WORKSHOP

Variability in Atmospheric Deposition and Stream Chemistry Fluctuations

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An atmospheric deposition monitoring network was established in Pennsylvania in 1981 to determine the magnitude and distribution of atmospheric deposition and associated toxic and nutrient elements. An additional function is to assess the potential environmental impacts, both detrimental and beneficial. Samples of weekly precipitation were collected at 12 sites in 1982 and 13 sites in 1983 and 1984, including two National Atmospheric Deposition Program (NADP) sites. These were analyzed for pH, specific conductance, sulfate, nitrate, ammonium nitrogen, chloride, sodium, potassium, calcium, and magnesium. Based on the results from this monitoring network, precipitation in Pennsylvania can be characterized as a dilute aqueous solution of sulfuric and nitric acids. Although precipitation in certain areas of the State is more acid than others, precipitation over the entire State can be characterized as very acidic. In general, precipitation in the eastern third of the State is less acidic than the rest of the Commonwealth. The most acidic precipitation falls in the southwest portion including an area as far east as Huntingdon county and as far north as Mercer County. The lowest pH measured since 1982 was 3.24. The statewide volume-weighted annual average pH was 4.13 in 1983 and 4.09 in 1982.

Because the amount and distribution of precipitation is highly variable within the State, the amount of precipitation plays an important role in determining which areas receive the greatest amount of wet deposition. Wet deposition of hydrogen, which is calculated using pH data and the amount of precipitation

that occurs during a sampling period, varied from 0.58 to 1.07 kg/ha/yr over the two year study period. The growing season receives the greatest amount of hydrogen deposition accounting for approximately 60% of the annual amount. East (low deposition) to west (high deposition) gradients are very evident.

Sulfate is the dominant anion in precipitation and is highly correlated with precipitation pH. Sulfate concentrations are highest in the western third of the State and decrease to the east. The highest mean annual volume-weighted concentration in 1982 and 1983 was measured in Centre County (3.52 mg/l), while the lowest concentration (1.68 mg/l) was measured in Pike County. On the basis of total deposition, precipitation contributed from 18.0 to 38.1 kg SO_4/ha to the surfaces of the State during 1982 and from 22.2 to 37.6 kg SO_4/ha in 1983. The majority of the deposition occurs during the growing season. In general, the area of lowest sulfate deposition occurs in the northeast quarter of the State, while the area of highest deposition occurs in the northwest and southwest quarters of the State.

Significant nitrate concentrations are also present in precipitation. In general, nitrate concentrations are less variable than sulfate concentrations. With some exceptions, nitrates are lowest in the eastern portion of the State and generally increased to the west. Nitrate concentrations in 1983 ranged from 1.51 to 2.18 mg/l and from 1.82 to 2.35 mg/l in 1982. Annual wet deposition of nitrate varied from 14.7 kg/ha/yr in Tioga County to 25.2 kg/ha/yr in Mercer County. Nitrate deposition over the State is fairly uniform, with the western portion of the State receiving slightly more nitrate than the eastern part of the Commonwealth.

Measurable concentrations of chloride, ammonium, calcium, potassium, sodium, and magnesium are also found in precipitation. The concentrations of chloride and sodium exhibit fairly definable spatial and temporal trends that can be associated with storm direction and the presence of sodium chloride salt from coastal influences. The highest concentrations of sodium and chloride are found along the eastern border of Pennsylvania. Ammonium concentrations in the State averaged less than 0.22 mg/l annually. The highest concentrations are measured in central Pennsylvania. Collectively, calcium, potassium and magnesium are found in precipitation at very low concentrations. Since they are essential plant nutrients and serve as buffering or neutralizing agents in the atmosphere, they can be considered as a beneficial component of atmospheric deposition.

Correlation analyses indicate that a strong association exists between the concentrations of hydrogen and sulfate and a relatively good association between hydrogen and nitrate concentrations in precipitation. Stepwise regression analysis support the correlation analyses. Regression analyses have shown a positive relationship between precipitation sulfate concentrations and hydrogen ion concentrations for all sites. Generally, the second most important ion is nitrate. Sulfate and nitrate concentrations, and to a lesser extent ammonium and potassium concentrations, when included in a regression model, can explain from 78 to 94 percent of the variation in hydrogen ion concentrations in precipitation depending upon site location. The results of the regression and correlation analyses appear to support the position that sulfur dioxide and nitrogen oxides emissions are the most important atmospheric pollutants contributing to the acidification of the precipitation in Pennsylvania.

Many reports have revealed that acid precipitation has caused a measurable decline in the pH and alkalinity of surface water and a corresponding alteration in the aquatic communities inhabiting these waters. Many of the conclusions found in the earlier reports were based on historic water quality data or more recent data obtained from a few observations. These results were, for the most part, restricted to long-term changes in water quality. Conclusions based on historic data are subject to debate because of problems in the data and their interpretation. Such problems result from seasonality of water quality parameters, inadequate numbers of observations, errors associated with different analytical techniques, fluctuations in quality due to change in the hydrologic status of a stream or lake, and intra-watershed variations in water quality. These problems become more pronounced as the number of observations decrease. In more recent years, attention has focused on episodic fluctuations in stream quality and its impact on aquatic organisms. Such fluctuations may be more serious than long-term changes in stream quality because aquatic organisms may not be able to acclimate themselves to their rapidly changing environment. A great deal of attention has also been devoted to assessing the nature and magnitude of the impact of acid precipitation on aquatic resources. The assessment process is hindered because of significant variations in atmospheric deposition over relatively small areas and intra-watershed variations in stream quality. In addition, fluctuations in stream quality during eposodic events also contribute to the assessment difficulties. The extent and magnitude of the acidification of our surface waters has not been adequately defined nor has a method been developed to do so. The establishment of a nationwide stream sampling network on our more pristine watersheds would help to answer many of the questions associated with long and

short-term acidification of our surface waters. Such a network would also provide a means of assessing the success of proposed federal regulations reducing the emissions of sulfur dioxide.

Acidification and Loss of Trout Populations in Vancampens Brook Delaware Water Gap National Recreation Area

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I'd like to just give you a brief summary of a study that we are planning to conduct concerning the possible effects of acidification on rainbow trout reproduction in Vancampens Brook. Vancampens Brook is a small stream that drains a portion of the Kittatinny Ridge in Sussex and Warren counties, New Jersey. The stream supports reproducing populations of three trout species - brook, brown and rainbow trout. Electrofishing data collected in 1977 indicated that each species occupied a more or less distinct portion of the stream, with little overlap in the habitat used by each. Brook trout were present in the headwater sections, rainbow trout in the middle reaches and brown trout in the downstream portion. In the middle portion of the stream, approximately from Millbrook Village downstream to the Watergate Recreation Area, the salmonid population was dominated by rainbow trout, which comprised 98% of the total salmonids. Additional sampling in 1978 confirmed the dominance of rainbow trout in this portion of the stream. No brook trout were found at that time.

Last year this same section of stream was electrofished and the data collected revealed a change in the trout populations. Rainbow trout, which had previously accounted for 98% of the total salmonids, had now declined to 64%.

Brook trout, which had previously been absent from this area, now accounted for 36% of total salmonids. In addition, young-of-the-year rainbow trout were very scarce, indicating poor reproductive success.

At about the same time that this biological data was obtained, we became aware of some water chemistry data that was collected by Dr. McIntosh in conjunction with his acid rain work in that area. His data indicated that during a spring snowmelt event the pH of Vancampens Brook had declined to 4.5 in the vicinity of Millbrook Village, an area utilized by rainbow trout for spawning. Rainbow trout are extremely sensitive to acidic conditions. They are also spring spawners, which means that pH depressions due to spring snowmelt events would tend to expose the sensitive early life stages of the trout to very stressful conditions. Brook trout, on the other hand, are fall spawners. They also tend to select areas of groundwater upwelling or seepage for spawning sites. The buffering capacity of the groundwater could provide some measure of protection forthe developing embroyoes and alevins in the gravel. Brook trout have also been found to be considerably more acid tolerant than rainbow trout. Taking all these factors into consideration, we began to wonder if the short-lived acidification events that occurred in the stream might be related to the population changes that we observed, that is, the decline in the numbers of rainbow trout and increase in the numbers of brook trout.

In order to find out whether or not this is the case, we will conduct both chemical and biological monitoring of the stream. The water chemistry portion of the study will consist of two parts. The first part will be periodic surface water quality analyses. The second part of the water chemistry portion of the study will consist of analyses of the intergravel water in the stream

bed. Spawning sites of brook and rainbow trout will be identified and plastic standpipes will be embedded in the spawning gravel. Samples of the intergravel water will be periodically collected from these standpipes. Both surface and intergravel water will be analyzed for pH, alkalinity, temperature, dissolved oxygen and the trace elements aluminum, lead and mercury.

Our reasons for looking at the chemistry of the intergravel water are twofold. First, it is the intergravel water to which the eggs, embryos and alevins are exposed during their critical developmental periods. Secondly, other researchers have shown that the pH of the intergravel water in the redds of salmonids can be significantly lower than that of the surface water. This is thought to be due to increased respiration in the developing trout as the water temperature rises in the spring and also to increased production of carbon dioxide by microorganisms in the substrate.

The reproductive success of the trout in different stream sections will be measured by the numbers of young-of-the-year captured by electrofishing. These data will be statistically compared to the water chemistry to identify relatonships between the various water chemistry parameters and the degree of reproductive success.

Several brook and rainbow trout redds will be excavated prior to emergence of the juveniles. Fish collected in this manner will be subjected to routine histological processing and examined under the light microscope for evidence of acid-induced tissue damage. In embryos, we will be looking specifically for abnormal development of the surficial ectoderm, a condition that has been observed in atlantic salmon embryos exposed to a pH of 4.5 in the laboratory. This condition can have a profound effect on the later development of the fish

because important organ systems will later develop from this tissue. In older fish, we will be looking for damage to the gill tissue which can result from exposure to low pH, heavy metals or a combination of the two. Fish tissues will be analyzed for heavy metals to look for enhanced uptake associated with the acidic conditions.

At the present time, there is very little information available on the effect of acid rain on fish populations in the state of New Jersey. We hope that the information obtained during the course of this study will tell us whether or not trout populations in Vancampens Brook are being adversely effected by acid deposition.

Trace Element Activity in Lakes Atop Kittatinny Ridge

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Trace element activity in six lakes atop Kittatinny Ridge is being assessed. Concentrations of aluminum, cadmium, lead, mercury and zinc in samples of water, sediment, aquatic plants, benthic macroinvertebrates and fish are being determined by atomic absorption spectrophotometric techniques on a seasonal basis.

Five of the lakes are highly acidic (pH less than 5.1) and have no measurable alkalinity; the sixth, Blue Mountain Lake, typically is characterized by a pH greater than 6 and low alkalinity. Composition of the biological community in the lakes is highly variable, with the most acidic systems, Long Pine Pond and Crater Lake, apparently supporting only one species of fish, yellow perch (*Perca flavescens*).

Initial analyses of water indicate that highest concentrations of aluminum, lead and zinc are found in the most acidic lakes, with maximum readings of 508 ug Al/l in Long Pine Pond and 95 ug Zn/l in Catfish Pond. Virtually all of the trace element burden in the water column occurs in the filterable or dissolved fraction. Sediment cores from three of the lakes indicate the presence of highly variable patterns of lead and zinc distribution over depth. Initial analyses of aquatic plant tissues indicate that in species from the most acidic lakes, lead levels greatly exceed those of zinc, a pattern not typically noted in non-acidified systems; such patterns may be an indication of altered biological availability of lead and zinc in affected systems.

Geochemical Control of $[H^+]$ in Lakes Receiving Acidic Deposition

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Seven fresh water lakes in northern New Jersey have been under surveillance for their reaction to acidic deposition. One lake, Catfish Pond, has been acidic for at least four years with pH values in the 4.58 to 5.64 range. The other six lakes have pH values in the 6.0 - 10.0 range. Some have "low" buffer capacities, less than -5×10^{-5} eq/l/pH. These lakes are considered to be threatened by acidic deposition. One of these "threatened" lakes, Clyde Potts Reservoir, maintained an alkalinity between 6.2 to 15. mg/l as $CaCO_3$ and an average pH value of 7.0 for over two years during an exceedingly wet period, >45"/year rainfall. Another lake, White Meadow, maintained unusually "high" alkalinities, 10.0 to 88.0 mg/l as $CaCO_3$, during the same period. Both of the lakes lie in the N.J. Highlands geologic province whose bedrock is largely Precambrian gneiss.

Bottom sediments were collected from the seven lakes wherein these aluminosilicates were detected: chlorite, illite, kaolinite, and, perhaps, vermiculite. Quartz ($SiO_{2(s)}$) was found also. It was postulated that chemical weathering reactions: ion exchange and acidic dissolution would be dominant factors controlling the $[H^+]$ in the overlying waters. Consequently, nine geochemical weathering models were written and examined for their ability to predict pH values in agreement with measured pH values. Dissolution products were: Al^{3+}, Na^+, K^+, $H_4SiO_{4(aq)}$, $SiO_{2(s)}$, kaolinite, and gibbsite. Ionic and dissolved silica concentrations were inserted into the several models from which $[H^+]$ were obtained.

Excellent agreement was obtained from muscovite-gibbsite-kaolinite model for pHcal with pHlab. For Catfish Pond, acidic dissolution models of muscovite and kaolinite also gave excellent agreement between pHcal and pHlab. Therefore, it appears that bottom sediments of lakes serve as acidic "sinks" and neutralize overlying waters. This observation also suggests a technique for renovation of acidified lakes. That is, aluminosilicates could be added whereupon the weathering reactions would maintain neutral pH values. This experiment was performed inadvertently in Clyde Potts Reservoir where bentonite was added for leakage control. The opposite to neutralization by aluminosilicates is seen in Catfish Pond. Here the weathering has proceeded perhaps beyond the ion exchange reaction to the dissolution of the sediments.

Acidification of Head Water Streams in the New Jersey Pinelands

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The effects of acidic deposition on the surface waters of the New Jersey Pine Barrens are still uncertain (Morgan 1984). Although precipitation in the region is highly acidic, this acidity is not necessarily transferred to surface waters. pH or H^+ is not a conservative parameter of the system. Numerous biogeochemical processes can both increase and decrease the acidity of the water that eventually reaches the stream. A clear understanding of the rates and control of these processes is necessary before the impact of acidic deposition can be unambiguously described. In the Pinelands, iron and sulfur metabolism are key biogeochemical processes affecting acidity. Our present research is aimed at determining the role of these processes in controlling H^+ flux through the hydrologic system.

Previous reports of significant acidification of two headwater streams in the New Jersey Pinelands, presumably by acid deposition, are not supported by more recent data and a re-evaluation of the original data. For one stream, McDonalds Branch, there has been no significant decline in pH from 1958 to 1982. For the other, Oyster Creek, a significant decline in pH was observed from 1965 to 1982, but the data indicate that a return to normally low pH levels following a short term watershed disturbance in the mid-1960's is more likely to have been responsible than acid deposition.

Plan of Study for Atmospheric Deposition Effects on Water Resources in the New Jersey Pinelands

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U.S. Department of the Interior
Geological Survey

Funding source: Cooperative agreement between the U.S. Geological Survey and the State of New Jersey, Department of Environmental Protection

Project duration: October 1, 1983 to September 30, 1986

New Jersey is subject to substantial acidic deposition. Waters in the Pinelands, situated in the southern part of the state, may be especially susceptible to the effects of this deposition. The soils and geologic materials of the Pinelands have little buffering capacity; the surface and ground waters have low pH, low dissolved solids, and little or no alkalinity.

Three potential effects of acidic deposition are under investigation in this study: (1) the acidification of surface and ground waters, (2) increased mobilization of trace metals, and (3) deposition and increased accumulation of lead.

A watershed study has been initiated at McDonalds Branch basin, a 6 km^2 basin in the central part of the New Jersey Pinelands. The basin lies within the largely undisturbed Lebanon State Forest and contains a U.S. Geological Survey (USGS) hydrologic bench-mark station on McDonalds Branch. Water quality and streamflow data have been collected at the site by the USGS since 1963 and 1953, respectively, as part of routine monitoring programs. The objectives of this study are to: (1) examine the movement of hydrogen, sulfate, and nitrate ions throughout the hydrologic cycle in an attempt to clarify the mechanism of the possible recent acidification of streams; (2) examine the ground-water flow

system and determine the contributions of its components to streamflow and surface-water quality; (3) investigate the role of organic matter in the mobilization of metals, particularly lead and aluminum, and estimate the contribution of organic anions to the total anionic charge; and (4) develop conceptual hydrologic and chemical models to describe current effects and project probable future effects.

Samples are being collected of precipitation, throughfall, soil water, ground water, and surface waters. Precipitation is collected at the upstream and downstream ends of the basin. Throughfall is to be collected from the four major vegetative types in the basin: pitch pine, oak, red maple, and Atlantic white cedar. Soil water is collected from the O, A, and B horizons in the four major soil series in the basin: Atsion, Lakehurst, Lakewood, and Evesboro. Ground water is collected from wells located in downgradient order along ground-water flow paths in a hardwood swamp, a transitional fen, and a cedar swamp. Surface water is collected at approximately five sites along the stream.

Temperature, pH, and specific conductance of water samples are measured in the field, or immediately following collection in the laboratory. Major cations (calcium, magnesium, sodium, potassium, and ammonium), major anions (sulfate, nitrate, choride, phosphate, and flouride), selected trace metals (aluminum, iron, manganese, and lead), dissolved organic carbon, pH, specific conductance, acidity, and alkalinity are analyzed at the USGS laboratory. Alkalinity and acidity are also determined by the Gran titration method.

Precipitation volume is measured at both precipitation stations in the basin,

and throughfall volumes are to be measured at the four throughfall-collecting sites. Volumes of soil-water samples are recorded. Ground-water levels are measured in 66 wells in the basin. Stream-stage levels are continuously recorded at the McDonalds Branch gaging station, and daily stream dicharges are computed based on measured stage-discharge relationships. Stream-stage levels are also measured at three additional sites on the stream.

Contour maps of the potentiometric surface are being compiled for the basin, and a flow net and water budget for the basin are to be developed. Conceptual models of ground-water flow and simple quantitative flow models are to be developed.

Clay lenses underlie parts of the basin and probably alter the flow of ground water and its chemistry; the lateral and vertical extent of major clay lenses in the basin is being defined. Geologic sections are being developed, and grain-size distribution, mineralogy, and some elemental analyses of samples from the Cohansey and possibly Beacon Hill Formations, including clays, are being determined.

Water-quality samples are collected weekly and composited to monthly samples for precipitation and throughfall; monthly for surface and soil waters; and bimonthly for ground water. Chemical budgets are to be calculated for the watershed. Conceptual models of the chemical system and its relation to the hydrologic system are being developed. Geochemical models are to be used to aid in identifying the chemical processes occurring in the system.

Preliminary results of the study indicate that the anionic composition of waters in the watershed is dominated by sulfate, not organic anions. the

sources of sulfate are as yet undefined, although acidic deposition is one. Other possible sources may be ocean aerosols, hydrogen sulfide produced in wetlands and sulfide minerals.

The sulfate adsorption capacity of the four predominant soil series in the basin has been experimently determined by the shaker flask method. The soils appear to be saturated with sulfate, and their sulfate adsorption capacity appears to be low. Saturation of available sites for sulfate adsorption may promote sulfate mobility and may enhance cation leaching from soils into ground and surface waters.

Sensitivity of Pocono Lakes to Acidification: Preliminary Results of an Ongoing Monitoring Program

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The Pocono Plateau of northeastern Pennsylvania is a significant recreational area containing a high density of multiple-use lakes. Approximately one-half of the Commonwealth's natural lakes (not man-made and not impounded by artificial structures) fall within Wayne and Pike counties. This same region has been shown to have received one of the highest hydrogen ion loadings of anywhere in the country over the past few years (Wisniewski and Kietz, 1983).

In April 1983, the Academy's Division of Environmental Research initiated a lake district monitoring program as one element of a comprehensive group of paleoecological and field studies designed both to document present and future water quality trends within the region and to investigate buffering mechanisms existing within individual drainage basins. Thirty-eight natural lakes lying within Wayne and Pike counties are being monitored for seasonal changes in pH, alkalinity, and 20 additional parameters including nutrients and metals.

Survey data obtained on the lakes during April and early May 1983 indicate that 34 of 37 lakes sampled would be classified as 'sensitive' to acidification with mid-depth alkalinities falling below 200 ueq/l. Subsequent sampling in August 1983 and throughout the first four months of 1984 has provided a preliminary estimate of seasonal variability throughout the lake set. The lakes form a geographically definable gradient from highly sensitive to non-sensitive based

on alkalinity and pH characteristics. A number of interrelating factors may be acting to produce the observed pattern, including soil and bedrock types, land use, in-lake processes and depositition patterns.

A comparison of April data for 1983 vs. 1984 indicates that both pH and alkalinity were generally higher within the district's most sensitive lakes in 1984. The increases may be related to diminished acid loadings and/or the manner in which the late-winter melt occurred in respective years.

Research on Acidification Effects, Sensitivity, and Mitigation in Streams and Lakes of Pennsylvania and Adjacent States

Presented at Delaware Water Gap National Recreation Area

January 18, 1985

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Studies of acid precipitation effects by the Pennsylvania Cooperative Fish and Wildlife Research Unit have primarily involved three general topics: 1) assessment of the extent of waters at risk; 2) effects of acidity on organisms in the fish food chain; and 3) development and assessment of devices for maintaining or raising the pH and alkalinity of streams vulnerable to acidification. We have also been responsible for the fisheries portion of the lake studies in the Pocono Mountains described by Dr. Bradt in her earlier presentation.

We determined a large suite of chemical and physical parameters in 278 unpolluted, relatively undeveloped, low order lakes and streams of the nine Middle Atlantic states (NY, PA, NJ, DE, MD, TN, NC, VA, and WV). About 45% of these waters were judged sensitive to acidification on the basis of alkalinity and calcite saturation index. Comparisons with historical data indicated that about 75% of the study sites have decreased in alkalinity (acid neutralizing capacity) in recent years. Alkalinity is a better predictor of sensitivity than are bedrock and soil characteristics, which have been widely used.

Brook trout from low alkalinity streams grew more slowly than those from higher alkalinity streams, and had higher whole body zinc concentrations even where

there was no difference in ambient zinc levels. Low pH alone does not appear to limit brook trout growth but may cause synergistic effects detrimental to fish with calcium and metals in low alkalinity waters. Brook trout in a low alkalinity, acidic stream generally matured one year earlier (at age 1+) than those in similar but less acidic streams. They also tended to produce larger but fewer ova. This suggests a selection for increased survival of fry in the absence of an adequate food supply by provisioning each fry with more yolk.

Low pH appears to affect species composition of periphyton but not species number or diversity in otherwise similar streams. These differences in periphyton composition seem to be reflected in a lower number of herbivorous insect species. This in turn causes a lower proportion of carnivores to detritivores in the insect communities of acidic streams as compared to otherwise similar circumneutral streams.

Limestone-filled gabion barriers, while showing some promise and having the advantages of low cost and low maintenance, have not yet been developed to the point of being effective acid neutralizing devices for woodland streams.

Biological and Chemical Changes in Three Pocono Lakes Sensitive to Acidification

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A survey in spring 1981 of ten Pocono (Monroe, Pike and Wayne Counties) lakes considered to be at high risk from acid deposition indicated that all ten lakes were sensitive to acidification. Three lakes were then chosen to study intensively biologically and chemically for two and a half years. The three study lakes represented a continuum from acidified Deep Lake (total alkalinity = 0 ueq/l), through extremely sensitive Lake Lacawac (total alkalinity = 45 ueq/l) to moderately sensitive Long Pond (total alkalinity = 115 ueq/l).

Over the study period statistically significant changes considered indicative of acidification were documented in both the biology and chemistry of all three lakes. These include: 1) increases in acid tolerant invertebrates and algae; 2) decreases in acid sensitive organisms; 3) increases in magnesium and 4) decreases in total alkalinity, hardness and specific conductance. Significant biological and chemical differences among the lakes were also documented. These include: 1) fewer acid sensitive invertebrates and fewer algal, invertebrate and fish species at Deep Lake; 2) more acid sensitive invertebrates species at Long Pond; 3) greater water transparency and higher aluminum levels at Deep Lake; and 4) higher calcium, magnesium, total alkalinity, specific conductivity and hardness at Long Pond. Lake Lacawac was continually intermediate between Deep Lake and Long Pond, both biologically and chemically. Total organic carbon was low in all three lakes, maximum level was 5.3 mg/l at Lake Lacawac.

The reason for the differences in the chemical reactions of the lakes to an apparently similar input of precipitation, in both quantity and chemistry, appears to be the differences in surficial geology and in the hydrological pathways among the three lakes.

Current work includes a similar biological and chemical study of two Pike County lakes but 2.5 tons/acre of agricultural limestone ($CaCO_3$) will be added to one of the lakes in winter 1985. Both lakes will then be monitored biologically and chemically for two years.

Vital Statistics Concerning the Impact of Acid Deposition on Pennsylvania Trout Streams with Comparisons Prepared for the Delaware River Basin

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Statewide:

An estimated 5,000 miles of trout streams stocked and unstocked, were made vulnerable to further acidification by 1981 (ALK$\leq$10 PPM).

The economic impact of the loss of these streams would be $100 million per annum based upon current angler day values.

Average alkalinity of smaller, pristine mountain streams has dropped from 21 PPM to 9 PPM from 1965 to 1981.

Over a third of the vulnerable streams have an alkalinity of 5 PPM or less, and are classed as in imminent danger of becoming unable to support fish year-round.

The most critically impacted streams are small, high quality fisheries. Over half of our highest management class waters, and of our first and second (size) order streams in the state are now vulnerable.

Delaware River Sub-basins

Sub-basin 1 - above Lehigh river

Stream sections surveyed and vulnerable:

Managed	Vulnerable	Total	Vulnerable
71	25	116	43

Sub-basin 2 - Lehigh to Neshiminy

Stream sections surveyed and vulnerable:

Managed	Vulnerable	Total	Vulnerable
79	34	127	54

Totals - sub-basins 1 and 2

Surveyed	Vulnerable	Imminent Danger
243	97	45

THE EFFECT OF ACID PRECIPITATION ON AMPHIBIANS IN TEMPORARY FOREST PONDS

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The majority of central Pennsylvania's temporary forest ponds are extremely dilute and acidic. Ion concentrations (Na, K, Ca, Cl) ranged from 0.3 to 2.0 mg/l while Al was positively correlated with pond acidity and reached concentrations as high as 0.6 mg/l. Our study ponds may be divided into three groups: 1) high pH ponds (6.0-7.0) resulting from anthropogenic inputs of calcium: 2) low pH (4.5-6.0) dark water ponds; 3) very low pH (4.0-4/5) clear water ponds lined with or filled with Sphagnum. We feel the high concentration of organic acids in group 2 ponds are responsible for their low pH. Group 3 ponds are acidic due to the Sphagnum's ability to exchange H^+ ions for Ca. although rainfall events did not have a significant effect on pond pH or alkalinity, acid deposition may still be having a significant impact on these ponds. Acidic snow-melt may be influencing pond pH's since they are lowest in pH during early spring immediately after filling. Small depressions in pond pH (0-0.2 units) would have great biological implications since most species are existing in ponds only marginally above the lower incipient lethal pH. Further declines in pH would mean certain elimination. The extremely dilute nature (0.3-1.0 mg/l Ca) and low alkalinity of most temporary forest ponds warrants further research and careful monitoring of these delicate aquatic systems in the face of continuing acidic precipitation.

The main cause of mortality in amphibian larvae exposed to low pH is loss of the ability to regulate body ion (Na and Cl) content. Inhibition of sodium

influx and huge increases in sodium efflux occur, resulting in death when 50% of the body sodium content is lost. Elevated calcium concentrations can reduce larval and embryonic mortality due to its ability to lower the lethal sodium efflux. This phenomenon has considerable theoretical potential as a short term mitigation strategy in acid deposition impacted ponds. Sensitive amphibian species (*Ambystoma sp.*) are missing from ponds below pH 4.5 and embroyos transplanted into these ponds died. Embryonic mortality is controlled by a complex interaction between pH and concentrations of Al and organic compounds.

RECOMMENDATIONS

The goal of the National Park Service is the preservation, through management, of natural and cultural resources. The prerequisite for wise management is knowledge of the systems, whether they are natural ecosystems or cultural artifacts, that are to be maintained. This particularly holds true for natural ecosystems. A manager who is well informed about the natural variability and response mechanisms of a system will be exposed to far fewer surprises that could be misinterpreted as something gone awry. Furthermore, knowledge of ecosystem cause and effect may allow for prevention rather than mitigation of many man-caused problems.

Atmospheric deposition in the Eastern United States encompasses a number of complex processes. No one agency can hope to have the resources necessary for assessing the causes, magnitude, environmental effects, or mitigation approaches that fall under the category of atmospheric deposition research. Fortunately, there is research already underway at all geographic levels, local, regional, national and international. It was demonstrated at the workshop that Delaware Water Gap NRA has an immense amount of local information and expertise aleady at its disposal. In addition, investigators from other parts of the East, from around the United States, and from Canada and Europe are gathering information on the causes and effects of this serious environmental problem. Hopefully, the results of these studies will lead to an understanding of the degree and expanse of the problem at the same time that lasting solutions are being identified and implemented.

What follows is a discussion of recommendations for the management of resources affected or threatened by acidic atmospheric deposition in Delaware Water Gap

National Recreation Area. The are itemized by the categories introduced in the Workshop Summary, but they are further distinguished as wanted programs versus needed programs. This is meant to help in resource management prioritization, an exercise every National Park Service unit with limited funding and manpower must undertake.

DEPOSITION

Wet deposition chemistry is monitored weekly at Gifford Pinchot Institute for Conservation Studies, and data are available upon request from either NADP or Jim Lynch of the Pennsylvania State network. The Recreation Area is so close to this site that the data can be used with confidence of its representativeness. Additional monitoring by the Area, unless for a very site specific need, would be a duplication of effort.

SENSITIVE RESOURCES

Resources at Risk

Resources at risk were well-described at the workshop and include lakes and streams located on top of or draining from the Kittatinny Ridge, the flora and fauna of these lakes and streams, temporary forest ponds that are breeding grounds for amphibians, and a resource not discussed at the workshop, coniferous forests. A priority list can be developed for work to be done under this category. Area staff may need to monitor the status of some of these resources, for they are important and sensitive enough not to be neglected. Study of some of these resources by outside investigators is ongoing and continuation will be encouraged.

A report by Bruce Pyle and Bill Stansley in this Proceedings discusses brook and rainbow trout in Vancampens Brook. Declines in rainbow trout populations

and increases in brook trout populations were noted between 1977 and 1984, while water chemistry during this period has been shown to drop to a pH of 4.5. Since one source for Vancampens Brook, Long Pine Pond, is acidic beyond a shadow of a doubt,there might be a relation between these population shifts and stream acidification. Spring-spawning fish, such as rainbow trout, have been documented as being more sensitive to acidic 'shocks' that often accompany melting of winter snows in acidified regions of the world. A minimum monitoring program would involve stream pH measurements in the springtime, when rainbow are spawning. An optimum monitoring program would involve regular sampling of stream chemical and physical parameters, coupled with yearly population studies of both brook and rainbow trout. Chemical parameters include pH, specific conductance, sulfate, nitrate, chloride, inorganic phosphate, calcium, sodium, magnesium, potassium, ammonium, and perhaps inorganic monomeric aluminum. Physical parameters might include temperature and flow. If Vancampens Brook is indeed undergoing acidification, a mitigation program might be considered. We encourage Pyle and Stansley to continue their work in Delaware Water Gap NRA.

Joseph Freda sampled temporary forest ponds in Delaware Water Gap in spring 1985. These ponds are important breeding sites for spotted and Jefferson salamanders, wood frogs, spring peepers, and spotted turtles. None of the ponds were acidic, and amphibian populations appeared to be healthy. Freda suggests, however, that future problems cannot be ruled out. "The precipitation and snowmelt in eastern Pennsylvania is very acidic (pH 3.8 to 4.4), but is (currently) being buffered by leaf litter on the forest floor or organic sediments within ponds. These sources of buffering capacity are not

infinite" (Freda 1985). He recommends follow-up surveys. These might be scheduled on a five-year recurring basis, perhaps utilizing volunteer help.

Lake chemistry and biota, particulary macrophytes, appear to be under adequate study in Delaware Water Gap NRA. Continuation of this work will be encouraged. Additional work on the algal composition of these lakes, coupled with a paleolimnological study of algal diatom assemblages through time would help greatly to interpret whether current lake chemistry is a product of an acidification process. While this work falls under the 'want', rather than 'need' category, its importance will rise considerably if mitigation techniques to raise lake pH levels come under consideration. A prerequisite to any restoration work is a knowledge of historical lake chemistry data.

Other aquatic survey work which is welcomed on an opportunistic basis includes assessment of the effects of acidification on benthic macroinvertebrates, zooplankton and other animals, such as waterfowl, that forage from open waters.

Many universities and federal agencies are currently studying how soils respond to acidification. There is a NAPAP-sponsored program attempting to derive meaningful predictors of soil sensitivity from existing Soil Conservation Service surveys. If this program is successful, Delaware Water Gap NRA managers will be able to apply the results to those Area soils that have been surveyed. Although soils work within the Area is not necessary at this time, independent studies will be welcomed.

Throughout the east and northeast coniferous forests are showing reduced vigor, slower growth rates, and greater susceptibility to disease, and the cause is thought to be some combination of air pollutants. The situation in this

country seems to be following the same pattern that has caused up to fifty percent forest mortality in some parts of northern Europe. Very little is as yet known about the mechanisms responsible for forest decline, but as more information becomes available, Delaware Water Gap may want to survey for symptoms of forest damage.

Delaware Water Gap NRA may also have cultural resources susceptible to degradation from acidic deposition. A survey and documentation of these resources should be conducted. Park managers are encouraged to contact Susan Sherwood of the National Park Service Washington Office for more information on this subject.

Processes

While process work is scientifically very exciting, it is not always necessary to have such work conducted within National Park Service unit boundaries for the results to be applicable. The findings of Arnold and Bradt on the feasibility of different liming techniques will be of value to Delaware Water Gap NRA should liming be considered. Similarly, the process work of Morgan and Lord in the New Jersey Pinelands will shed light on the mechanisms responsible for stream and lake acidification. The processes will be universal while the proportions of components may vary from site to site. This is where survey data become very important because knowing how to apply the mechanistic results of other researchers specifically to Delaware Water Gap NRA makes the difference between informed management and blind reaction.

There are circumstances in National Park Service units where process-oriented research should be encouraged, and possibly funded. Circumstances will vary

from park to park, but most will include the occurrence of unique or special resources. Delaware Water Gap NRA has such a special resource in Vancampens Brook, which is fed by two first-order streams. One drains from acidified Long Pine Pond and the other originates from the unacidified Blue Mountain Lakes. An assessment of the chemical and biological differences between the tributaries and Vancampens Brook would make a very interesting study. Vancampens Brook has additional value because of its trout fisheries. While there are many considerations that enter into a decision to promote or conduct such research, Delaware Water Gap NRA managers should be aware of this scientific opportunity.

MITIGATION TECHNIQUES

Given the state of our knowledge concerning the causes and effects of acidification, it often becomes a political decision to mitigate lake or stream acidity. Any permanent solution to "acid rain" must come from a reduction in sulfur and nitrogen oxide emissions from fossil fuel combustion. Other mitigation techniques, such as liming, are temporary and must be viewed as stopgap measures. Liming is expensive and some of its ecological effects are still in dispute. While mitigation work is not recommended at this time, the Delaware Water Gap NRA may wish to consider it as a last resort if needed to maintain trout fisheries in Vancampens Brook or for restoring fisheries to lakes on the Kittatinny Ridge.

STAYING CURRENT - MAINTAINING LEVELS OF INFORMATION

Continued communication and cooperation with the acidic deposition research community is perhaps the most important recommendation to be made regarding future work in Delaware Water Gap NRA. Excellent progress has been made in

attracting outside investigators to the area to address complex atmospheric deposition questions. In part this is due to the unique resources available such as sensitive streams, acidified lakes, and slow-weathering parent material. It is also due to the willingness of park managers to facilitate research within park boundaries. When possible, this should be continued. A continued dialogue between outside researchers and Recreation Area staff will ease the burden of logistic requests and ensure that research results get reported to the park. This dialogue will also help to keep researchers informed of potential alterations to study areas due to emergencies.

To conclude, Delaware Water Gap National Recreation Area has made an excellent move toward understanding how atmospheric deposition will influence the natural resources of this lovely eastern park. Future responsibilities include fostering continued communication with local researchers and with the national atmospheric deposition research community. Provisions for monitoring of the status of sensitive resources should be made to include continued assistance from local investigators and/or park staff time and funds. Should acidification continue in Vancampens Brook the park may wish to consider mitigation techniques. Managers at Delaware Water Gap have laid the groundwork already for these activities by writing a comprehensive Resource Management Plan, by hosting this workshop, and following through with surveys of resources at risk. NPS acidic deposition staff will be available to assist in any way possible.

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